THE SKATE

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THE SKATE, RAJA ERINACEA MITCHILL.

The skate, Raja erinacea Mitchill, belongs to the Class Pisces: subclass, Elasmobranchii: cartilaginous skeletoned fish that show the presence of a representative of the original notochord in soft diamond-shaped masses between the vertebrae.

The skate as a dorso-ventrally flattened, bottom living form is an admirable type for dissection, especially of the nervous system which is almost diagrammatic in its arrangement. The order Plagiostomi embraces the sharks (including dogfishes), the skates and rays. Two species of skates, family Raiidae, may be found in the material for dissection. The most frequent species is the common skate, little skate, or tobacco-box, Raja erinacea Mitchill, but occasionally specimens of the ocellated or big skate, Raja diaphanes Mitchill, may be present. Both these species are found on the north Atlantic coast. Skates are distinguished as long snouted in contrast to the short snouted rays.

Directions for the Dissection of the Skate Raja erinacea Mitchill

Identify:

A.—On the Dorsal Surface:

1. Eyes. Eyelids are absent as in most aquatic vertebrates. Note shape of pupil and flattened cornea.
2. Spiracles—Two large ovoid openings behind the eyes which lead into the mouth. These are passages for the intake of water in respiration.
3. Sensory pores—numerous small pores upon the surface of the head. These are found in the neighborhood of the snout and in a very definite arrangement about the eyes. By pressing on the surface the pores can be more clearly demonstrated by the mucous which exudes through them from the tubes. The lateral line system in ordinary fish is homologous with the dorsal and ventral tubes and pores.
4. Endolymphatic pores—a pair of small openings on the dorsal surface of the head posterior to and slightly medial to the eyes. The ducts from these lead into the internal ears.

5. Placoid scales, each produced into a spine—Each scale consists of dentine covered by enamel. Note the arrangement. In this species there are no spines ordinarily in the middle line of the tail.
6. Two dorsal fins and one very small caudal—all grouped near the end of the tail. This is a decided modification from the ordinary fish type in which the dorsal fins are farther forward. Note also small lateral folds at each side of the tail.

B.—On the Ventral Surface:

1. Mouth—Note the shape of the teeth. The younger, sharper and smaller teeth are on the inside and the older, flatter and larger are on the outside and ready to be cast off. The number of series (young to old) is characteristic of the species. Count them. R. erinacea 45; R. diaphanes 90 (in each jaw).
2. Nostrils—Probe them. Is there an opening into the mouth? Note the flaps which aid in directing a current of water into and out of the nostrils. The function of the olfactory pits in the skate is purely sensory.
3. Gill clefts—Count them. Each leads into a gill pouch in which are located the gill filaments. Probe one.
4. The Coracoid cartilage of the pectoral girdle can be felt as a bar extending across the body just posterior to the gill clefts. This helps to support the immense pectoral fins which are specialized in skates in association with the bottom living habit. This is a very different body form fr that of the typical fish.
5. Sensory tubes and pores—Owing t the unpigmented nature of the skin on the under surface of the pectoral fins the numerous wavy lines are most easily seen there.
6. Pelvic Girdle with pelvic fins and in the male, the claspers, grooved rod-like projections from the medial surface of the pelvic fins. The claspers are hinged at the base and serve as copulatory organs. The seminal groove lies on the outer side.
7. Anus or Vent—Opens into the cloaca, a chamber into which the rectum and the urinogenital tubes open.
8. Abdominal pores—Two openings into the abdominal cavity at either side of the anus. The function of these is unknown but they are similar in relationship to segmental openings.

Make two drawings to illustrate the above mentioned parts.

Digestive System

Make a median ventral incision through the abdominal wall from a point just behind the pectoral girdle to the anus. Cut through the pubic region of the Pelvic Girdle. Make a transverse incision through the body wall on each side and pin back the four flaps.

Identify the following structures without tearing or cutting any part.

1. Peritoneum—Parietal and Visceral.
2. Mesenteries—Meso-gastrium, meso-rectum. Note absence of intestinal mesentery; cf. Mammal.
3. Omenta—Hepato-duodenal; hepato-gastric; gastro-splenic.
4. Liver—consists of three lobes; the gall-bladder is situated between right and middle lobes. The bile duct is a small tube leading from liver to duodenum.
5. Oesophagus—Lift up liver and observe this wide short tube from the mouth.
6. Stomach—a U-shaped structure consisting of cardiac and pyloric limbs.
7. Pyloric valve—a muscular constriction which divides stomach from duodenum.
8. Duodenum—a short portion in which are the openings of the bile-duct and the pancreatic duct.
9. Pancreas—consisting of dorsal and ventral lobes between the stomach and the duodenum.
10. Spiral valve region of the intestine—note on the surface the line of attachment of the valve. The blood vessels follow the line of the spiral valve.
11. Rectal Gland—a finger-like projection at the posterior end of the spiral valve region.
12. Rectum—remainder of intestine opening into cloaca.
13. Spleen—attached by the gastro-splenic omentum to the stomach. A gland on the circulatory system (not digestive).

Spread out the parts, but keep them in their proper relative positions and make a semi-diagrammatic drawing of the digestive system and spleen only.

Circulatory System (posterior part of the body)

A. Arteries (filled with yellow injection mass).

Dorsal Aorta—Mid-dorsal line. The following branches arise from it:

1. Coeliac—divides into
   A. Gastro-hepatic—which gives off
      Gastric to lesser curvature and spleen.
      Hepatic to liver along gastro-hepatic omentum.
   B. Gastro-duodenal — to greater curvature of stomach, pancreas and duodenum.
2. Superior Mesenteric—to spiral valve region (gives off a small branch to spleen, pancreas and duodenum).
3. Inferior Mesenteric—to rectal gland and rectum. Gives off spermatic arteries to gonads (and in female, a branch to the oviduct).
4. Segmental arteries—a series of small vessels passing to the muscles of the dorsal wall.
5. Renal—a series of small paired vessels to the kidneys.
6. Iliac—remove the peritoneum in the angle of the coelome postero-lateral to the kidney and note these vessels passing to the pelvic fins. (Do not try to trace them from the aorta at present).
7. Caudal—continuation of abdominal aorta into tail. (Cannot be seen and should not be exposed at present).

Make a drawing of a ventral view to show the arrangement and distribution of the vessels named above.

Make a median ventral longitudinal incision forward from the coracoid to the level of the second gill cleft. Make transverse incisions at each end of the longitudinal incision and pin back the flaps to expose heart and pericardial cavity.

B. Heart.

1. Ventricle—conical and muscular.
2. Conus Arteriosus—leading anteriorly from ventricle (slightly to the right).
3. Atrium—dorsal to ventricle and projecting on each side.

4. Sinus Venosus—tip up ventricle and locate a part of a transverse, triangular thin-walled chamber of which the antero-median angle opens forward into the atrium dorsal to the ventricle. The ventricle is attached to the dorsal wall of the pericardium in the median line behind the sinus, which at this stage can be seen only at each side, where it extends laterally to receive the duct of Cuvier.

C. Veins.

Before proceeding in the female, note the anterior ends of the oviducts joining in a common ostium on the anteroventral aspect of the liver.

Cut carefully the coracoid and remove over the ducts of Cuvier—short lateral extensions of the sinus venosus.

Blood is returned from the posterior part of the body by:

1. Lateral veins—locate on lateral wall of coelome. Open into ducts of Cuvier. The lateral veins originate in small vessels from the side of the rectum and cloaca not usually easily seen and are joined posteriorly by the iliac veins from the pelvic fins. Anteriorly, each lateral vein is joined by two pectoral or brachial veins from the pectoral fin. One of these passes between the metapterygium and the coracoid into the lateral vein after coming from the more posterior part of the fin beside the posterior branch of the subclavian artery. The other passes between the mesopterygium and the coracoid after coming from the more anterior part of the fin beside the anterior branch of the artery. A series of small tributaries lying just under the peritoneum enter the lateral vein from the body wall.
2. Right and Left Postcardinals — between the kidneys — the caudal vein gives rise to right and left renal portals dorsal to the kidney (do not try to find these at present). These enter the kidney and form capillaries which collect to form the right and left postcardinals. These latter anastomose between the kidneys and open forward into large posterior cardinal sinuses, which are thin-walled and communicate across the midline.
3. Hepatic Portal System—blood from digestive organs and spleen by (a) Superior mesenteric vein, (b) Gastro-duodenal vein, (c) Gastric vein. Each of these parallels the distal part of the corresponding arteries and they unite in the hepato-

duodenal omentum to form the portal vein, which passes with the bile duct and hepatic artery to the liver. The hepatic portal in the liver forms capillaries, which reunite to form the hepatic veins, which open into the hepatic sinuses. The latter join the ducts of Cuvier.

Cut open the anterior part of the liver to see the hepatic veins.

Circulatory System (anterior part of the body)

Cut open the ducts of Cuvier and locate the openings of the following by probing:

1. Inferior Jugular—opens into duct of Cuvier at dorso-lateral angle of pericardium; drains floor of mouth and pharynx.
2. Anterior Cardinal Vein—opens into duct of Cuvier dorsally.

N.B. Merely note the openings of these veins. Do not trace them.

Make a drawing to show the sinus venosus and all the veins found in the above description.

Cut through and turn aside the skin from in front of the conus arteriosus to the lower jaw, removing it as far laterally as the gill openings. Note the external hypobranchial artery ventro-medial to the gill clefts and the anterior coronary, which originates from it. Trace the ventral aorta through the muscle and find two branches on each side. The posterior breaks up into three, the anterior into two afferent branchial arteries to the gills.

Trace these to show how they are related to the gill clefts.

Draw heart, conus arteriosus, ventral aorta, afferent branchials and gill clefts.

Cut through lower and upper jaws and floor of pharynx, to right of heart, and turn parts aside. Carefully remove the lining of the roof of the pharynx, exposing the injected epibranchial arteries intact. Trace these out over the gills, on the left side, by slitting the mucous membrane and notice how they arise from the efferent branchial arteries and how the latter drain the gills.

Identify the following branches:

1. Common Carotid Artery—from the first epibranchial artery, dividing at the level of the anterior edge of the spiracle into 2 and 3.

2. Internal Carotid Artery—uniting with the corresponding artery of the opposite side to enter the cranium in the middle line.
3. External Carotid Artery—passing forward on either side to orbit, jaws and snout.
4. The posterior wall of the first gill cleft is drained by the first efferent branchial artery, which is joined by the efferent hyoidean from the anterior wall.

   The latter vessel gives rise to the afferent pseudobranchial artery which crosses below the external carotid and enters the cranium to unite with the internal carotid within the brain case.
5. Vertebral Artery — from near the junction of the first and second epibranchials, passing medially to penetrate the cranium.
6. Subclavian Artery—given off from the dorsal Aorta near the last pair of epibranchials; gives off oesophageal branches and the posterior coronary.
7. Posterior Coronary Artery—to the pericardium and sinus venosus.
8. Anterior Coronary Artery—to the conus arteriosus from the external hypobranchial artery, a longitudinal vessel formed by branches from the ventral ends of a varying number of the efferent branchial arteries. The external hypobranchial supplies arterial blood through branches to the gill septa and to the region medial to it and continues forward into the lower jaw region.

Make a drawing to illustrate the above arteries.

Interior of the Heart

With the scissors cut open the ventricle, conus arteriosus and a portion of the ventral aorta and note number and arrangement of the pocket valves on the wall of the conus arteriosus.

Make drawings to show the function of these. Examine the structure of the ventricle and the atrium and compare the heart structure with the mammalian type.

Respiratory System

Open a gill pouch on the right side and note:

1. Gills (Branchiae)—Each is supported by a cartilaginous bar, the branchial arch, from which a series of small rods, the branchial rays, extend through the septum.
2. Central Septum—dividing gill.
3. Demi-branch (Hemi-branch)—a series of gill filaments (or folds) attached on one side of a septum.

Make a drawing of a surface view of a demi-branch. Remove one gill, make a cross-section of it and show cartilage support, efferent and afferent branchial arteries, septum and gill filaments.

Interior of Alimentary Tract

Remove part of the alimentary tract by cutting across it through the oesophagus posterior to the liver and through the intestine just anterior to the rectal gland. Cut the arteries supplying it and remove. Slit the stomach and intestine open. Make a drawing to illustrate the changes in size of the lumen of the alimentary canal and show also the structure of the spiral valve. Cut across the tip of the rectal gland and examine it.

Urino-genital System

A.—in the male

1. Testis—a large, whitish, flattened body on each side.
2. Vasa Efferentia—numerous minute tubules passing, in the peritoneal attachment (mesorchium) of the testis, from its anterior end to the Wolffian duct.
3. Wolffian or Meso-nephritic Duct (vas deferens)—a long white coiled tube leading to the vesicula seminalis.
4. Vesicula Seminalis—the enlarged posterior end of the Wolffian Duct.
5. Sperm Sac—a large thin-walled sac lying beside the seminal vesicle.
6. Kidneys—flattened, roughly oval bodies lying dorsal to the seminal vesicles beneath a very thick layer of peritoneum. An anterior vestigeal portion underlies the Wolffian duct. The interrenal gland is a small body lying close to the medial edge of each kidney and having a more yellowish colour. It represents the cortex of the mammalian adrenal gland.
7. Ureter—a series of tubules passing from the kidney to the end of the seminal vesicles at the urinogenital sinus.

8. Urino-genital Sinus—a small common median chamber which opens through 9 into 10.
9. Urino-genital Pore—at the tip of the urino-genital papilla, opens into 10.
10. Cloaca—common chamber for the urino-genital system and the rectum.

Make a drawing of the Urino-genital System of the male and examine and draw the system in the female.

B.—in the female.

1. Ovaries—large flattened bodies on either side containing yellow Graafian follicles and attached medially by the mesovarium to the dorsal abdominal wall.
2. Oviducts—trace from common opening ventral to the oesophagus back on either side to the shell gland.
3. Shell-gland—a white bean-shaped swelling of the oviduct. The oviduct continues posteriorly to open into the cloaca.
4. Cloaca—a very thick walled chamber.
5. Kidney—consisting of an oval flattened mass on each side dorsal to the cloaca and beneath a heavy thick peritoneal layer. Interrenal gland (as in male).
6. Ureter—leading anteroventrad from the kidney to a dilated portion which opens into the urinary sinus.
7. Urinary sinus—which opens into the cloaca on its dorsal side.

Make a drawing of the ventral view of the female urino-genital organs and examine and draw the system in the male.

Vertebral Column

Make a clean cut across the tail just anterior to the point of injection and note:

1. Centrum—cartilage with calcareous deposits. If not cut near the middle of a vertebra it appears cup like.
2. Neural Arch—its pedicles rising dorsally from either side of the centrum, enclosing the neural canal.
3. Neural Canal—containing spinal cord and artery and vein to cord.
4. Neural Spine—extending dorsad from the neural arch. In this form it is flattened just under the skin.

5. Haemal Arch—its pedicles extending ventrad from either side of the centrum, enclosing the haemal canal.
6. Haemal Canal—containing caudal artery and vein.
7. Haemal Spine—extending ventrad from haemal arch. Pointed.
8. Muscles—note the arrangement.
9. Lateral Line Canal—a small, rather thick walled canal just under the skin at each side; and lateral cutaneous vein, a larger vessel close to the canal, usually containing blood.
10. Skin and Placoid Scales (Shagreen Denticles).

Draw to show all the parts mentioned.

Make a clean cut dorso-ventrally through the median plane of the vertebral column and examine the cut surface.

Note the arrangement of parts and especially the soft portion between each vertebra and the next. This soft tissue is the remnant of the notochord.

Renal Portal System

Dissecting from the lateral side, through the peritoneum, raise the kidneys from the muscle and note:

1. Renal Portal Vein—from the caudal vein.
2. Renal Artery—from the iliac artery.

   These run into the kidney substance parallel to each other.
3. Renal Arteries—from the dorsal aorta.

   The blood from the above three sources, after passing through the kidney, is collected by renal veins within the kidney substance. These empty into the cardinal veins.
4. Cardinal Veins—They anastomose between the kidneys posteriorly and pass anteriorly as the right and left posterior cardinals.

Draw blood supply to and drainage from the kidney.

Orbit of the Eye

Remove the skin from the surface of the head, being careful to leave the eye intact. Dissect around the eye with a probe, being careful not to break the muscles or nerves crossing the orbit and observe:

A. Dorsal to the eye:

1. Superficial Ophthalmic Nerve—a branch of the trigeminal (V cranial) and facial (VII cranial) nerves, passing anteriorly along the inner wall of the orbit.

2. Superior Rectus Muscle—passing from a posterior and ventral point of attachment to the middle of the dorsum of the eye. A flat muscle supplied by the oculomotor nerve (III cranial).
3. Anterior Rectus Muscle—a slender muscle passing from the same origin as the above and supplied by the same nerve. It is attached to the anterior part of the eye where it disappears under the insertion of 4.
4. Superior Oblique Muscle—which passes from the antero-medial wall of the orbit to the eye. Nerve supply—trochlear (IV cranial) nerve enters the orbit antero-dorsal to the optic peduncle.
5. Deep Ophthalmic Nerve—a branch of the trigeminal (V cranial nerve) running under the above-mentioned muscles, parallel to 1.
6. Optic Nerve—passing to the eye between the superior oblique and the anterior rectus muscles and under the deep ophthalmic nerve.
7. Optic Peduncle—a cartilaginous rod passing to the eye from the wall of the orbit just anterior to the origin of the recti muscles.
8. Oculo-motor Nerve—enters the orbit just above the origin of the optic peduncle. It gives branches to three recti and the inferior oblique (cf. 2, 3, 10 and 11).
9. Posterior (or External) Rectus Muscle—from common point of origin of the recti to the posterior edge of the eyeball. Nerve supply—the abducens (VI cranial) nerve.

B. Raise up the eye and note ventral to it:

10. Inferior Rectus Muscle—from common origin of the rec. to middle of ventral part of eye. Nerve supply—oculomotor (III cranial) nerve.
11. Inferior Oblique Muscle—from antero-inferior wall of the orbit to eye. Nerve supply—oculomotor (III cranial) nerve.

Make drawings to illustrate the above-mentioned parts.

Ear

There is no middle or external ear.

Internal Ear—an organ of equilibrium, though functioning also for hearing, lying in the mass of cartilage posterior to the eye and between the spiracle laterally and the wall of the cranium medially.

Clear the skin and muscle from the cartilage of this region and with the scalpel cut off thin horizontal slices of cartilage until a small tube appears containing a small, transparent, membranous canal, the anterior semi-circular canal. Now, with forceps chop off small bits of cartilage until the horizontal semi-circular canal appears lateral to the anterior, and the posterior semi-circular canal posterior to both the others. Work under these canals, removing any cartilage around them and then working between the cartilage wall and the large sac to which the canals are attached, free the internal ear and lift it out of the cavity. Float one specimen in a salt-cellar in tap-water and identify:

1. Sacculus—the large sac.
2. Otoconia—calcareous masses corresponding with the hard otoliths found in Teleosts (bony fish).
3. Endolymphatic duct—a tube leading to a pore on the surface from the dorso-medial extremity of the sacculus.
4. Anterior Semi-circular Canal.
5. Horizontal Semi-circular Canal.
6. Posterior Semi-circular Canal, almost a complete circle.
7. Ampullae—one on each canal. Note the sensory epithelium supplied by branches of the VIIIth cranial nerve.
8. Utriculus—an oblique tube attached to the anterior surface of the sacculus. Note relation to anterior and horizontal canals.

Make a drawing illustrating the parts described above.

Nervous System

Brain—dorsal aspect

Remove the cartilaginous roof of the cranium and the dorsal part of the olfactory capsule, being careful not to cut any nerves. The following parts may be seen from a dorsal viewpoint without further dissection.

1. Prosencephalon. This consists of three parts:—
   (*a*) Olfactory bulb and tract. The elongated and only slightly swollen bulb lies upon the dorsal surface of the black olfactory sac in front of the eye. It is connected by the olfactory tract with the antero-lateral angle of the cerebral hemisphere. The superficial and deep ophthalmic nerves, described in the next section, cross these structures.

(*b*) Telencephalon. The telencephalon includes the two cerebral hemispheres and a small part of the brain immediately behind them. In the skate the hemispheres are fused into a large transverse mass. The telencephalon of the fish is almost entirely an olfactory correlation centre.

(*c*) Diencephalon. The narrow region just behind the telencephalon is the diencephalon, which encloses the greater part of the third ventricle. The roof of the ventricle is a thin membrane supporting the anterior chorioid plexus, while the masses forming its lateral walls are the thalami. These are higher reflex centres which are relatively unimportant in fishes. The small pineal body, which is attached to the roof of this region of the brain is not readily observed in gross dissection.

2. Mesencephalon. From a dorsal view, this is represented by the optic lobes, a pair of rounded eminences behind the third ventricle.

3. Rhombencephalon. This comprises two subdivisions:—

(*a*) Metencephalon. The rather large oval cerebellum overlaps the optic lobes in front and the medulla oblongata behind. It is concerned with motor co-ordination.

(*b*) Myelencephalon. The medulla oblongata tapers gradually backwards towards the spinal cord, into which it passes without any definite boundary being visible. It contains the centres for most of the cranial nerves, both sensory and motor.

At each side of the cerebellum the lateral wall of the oblongata bulges up as an irregular swelling, the acoustico-lateral lobe, which is the centre for the acoustic nerve and the nerves of the lateral line system.

The fourth ventricle, the cavity in the rhombencephalon, is covered largely by the cerebellum. Under the posterior end of the latter it is roofed by a thin membrane supporting the posterior chorioid plexus.

Spinal Cord. This should be observed extending backwards from the brain.

Cranial nerves. These should be dissected on one side only and should be followed to their peripheral areas of distribution.

I. Olfactory nerve. Numerous nerve fibres, not visible in ordinary dissection, pass from the nasal mucous membrane to the olfactory bulb.

II. Optic nerve. This arises in the retina and passes as a stout tract to the ventral aspect of the diencephalon.

III. Oculomotor nerve. Arising from the ventral aspect of the mid-brain and passing anterolaterad, the nerve pierces the wall of the cranium to enter the orbit just in front of the origin of the superior rectus muscle. Its distribution to the superior, inferior, and anterior recti and to the inferior oblique has been described in the section on the orbit.

IV. Trochlear nerve. This arises from the dorsal surface of the brain at the posterior end of the optic lobes, under the anterior part of the cerebellum. Passing anterolaterad, it crosses the oculomotor, somewhat dorsal to it, and emerges through the wall of the cranium further forward than the latter, passing to the superior oblique muscle.

VI. Abducens nerve. The abducens is mentioned next because, like the previous two, it is an eye muscle nerve. It cannot be seen at this stage of the dissection since it originates on the ventral surface of the medulla oblongata near the same level as the roots of the V-VII complex and passes into the orbit ventral to these. Here it at once enters the posterior rectus muscle. When the study of the remaining nerves has been completed they should be divided and raised so as to expose the abducens.

V-VII. Complex

The trigeminal (V) nerve rises by a large root and a smaller root from the side of the medulla oblongata, but these are partly concealed from a dorsal view by the roots of the facial (VII) nerve, which emerge from the brain dorsal and caudal to them. Both nerves contain both sensory and motor fibres. The fibres of these two groups of roots become closely associated and are distributed through the following main branches:

A. Superficial ophthalmic. This is a composite branch made up of a large component from the facial nerve and a small one from the trigeminal. The former supplies sense organs of

the lateral line system, the latter providing ordinary cutaneous sensibility to the region above the eye. The branch courses through the dorsomedial part of the orbit, where it has already been observed, and continues directly forward through the olfactory capsule to the dorsomedial part of the snout region, where it breaks into several rami. While passing through the cartilage of the olfactory capsule, it is joined by the deep ophthalmic branch, which unites with it, so that the two are distributed together. A branch from the superficial ophthalmic before it meets the deep ophthalmic, and another from the region where they are fused pass into the ventrolateral part of the snout.

B. Deep ophthalmic. The deep ophthalmic branch is derived from the trigeminal nerve and supplies cutaneous sensibility to the dorsal part of the snout region. After entering the posterior part of the orbit it passes dorsal to the posterior rectus muscle and ventral to the superior and anterior recti and to the superior oblique. Continuing forward through the olfactory capsule, it unites with the superficial ophthalmic, as described above. In the dogfish (Squalus) the nerve passes dorsal instead of ventral to the anterior rectus muscle.

C. Posterior ciliary nerve. This is a very small nerve of grayish colour arising as a branch of the trigeminus and running along the posterior margin of the ophthalmic peduncle to enter the eyeball.

The eye-muscles and the optic nerve and ophthalmic peduncle should be severed and the eyeball removed, whereupon the following branches passing through the ventral part of the orbit will be exposed.

A broad, flat band passing obliquely across the floor of the orbit from its posteromedial corner is the infraorbital trunk, which divides into three rami.

D. The most lateral branch from the infraorbital trunk is sometimes called the maxillary branch. It is distributed to the lateral part of the ventral surface of the snout.

E. The most medial is sometimes called the buccal branch. It runs straight forward medial to the olfactory capsule and is distributed to the ventromedial part of the snout, where it lies directly ventral to the ophthalmic.

In actual fact the maxillaris, which is a branch of nerve V conveying impulses of cutaneous sensibility, and the buccalis, which is a branch of nerve VII conveying sensory impulses from the tubules belonging to the lateral line system, are combined and send fibres into both these rami and into the smaller branches into which they break up.

F. Mandibular. Between the two branches just described appears a third which crosses the lateral ("max ·") branch ventrally and turns backwards ventral to the large mass of jaw muscles. In this it is distributed largely, but part of it curves round to pass mediad close to the lower jaw. The mandibularis is a branch of nerve V and contains both motor fibres to the jaw muscles and fibres of cutaneous sensibility.

G. Hyomandibular trunk. This large branch of the facial nerve passes in a posterior direction from its roots and turns dorsolaterad just behind the spiracle under the mass of muscle which lies in that situation. It crosses the hyomandibular cartilage, which connects the lateral ends of the jaws to the side of the cranium, and turns ventrolaterad, breaking into numerous branches. Some of these pass forward and mediad under the hyomandibular to provide sensibility for the anterior part of the mouth, others (motor) enter muscles belonging to the hyoid arch, while numerous lateral branches are distributed to ventrally situated ampullae of the l teral line system.

H. Palatine branch. The s all ramus palatinus leaves the hyomandibular as soon as it emerges from the sk ll, in the anteroventral part of the otic capsule, and passe anteroventrad, under cover of the muscles of the upper jaw, breaking into several branches which provide sensory innervation to the roof of the mouth and the anterior wall of the spiracle. The more posterior of these branches are considered to correspond with the prebranchial ramus of a typical branchial nerve, the facial being the nerve of the reduced gill cleft which is represented by the spiracle.

VIII. Auditory Nerve. The auditory nerve arises from the side of the medulla oblongata immediately behind the roots of the trigeminal and facial. It penetrates the otic capsule and branches to the sensory areas of the internal ear.

IX. Glossopharyngeal Nerve. Arising a short distance behind the auditory nerve, the glossopharyngeal runs posterolaterad through the floor of the otic capsule to reach the first gill cleft, where it divides into a small pre- and a large post-branchial branch. The former is purely sensory, the latter mixed sensory and motor. A small, sensory, anteroventrally directed, pharyngeal branch leaves the nerve before it emerges from its canal through the cartilage. These three branches are those typical of a branchial ner·

X. The vagus nerve arises from the side of the oblongata by a large anterior lateralis root and a row of smaller roots which emerge close together behind it. Passing through the posterior wall of the otic capsule, the nerve gives off a branch to the second gill cleft which forms three rami similar to those of nerve IX. Turning caudad, it gives off similar branches to the third and fourth gill clefts and then separates into dorsal and ventral divisions. The former of these is the lateral line nerve, which proceeds caudad internal to the muscles of the back until it reaches the level of the base of the tail, where it assumes a more superficial position near the lateral line canal. The ventral division gives off a fifth branchial ramus to the last gill cleft and then proceeds backwards as the visceral branch, which supplies the heart and stomach.

XI & XII. Spinal Accessory and Hypoglossal nerves are not found as distinct structures in animals lower than the r . nmals in the vertebrate series. The spinal accessory is represented in the posterior roots of nerve X, to which are added elements from the anterior spinal roots when it appears as a separate nerve. The hypoglossal is represented in the anterior spinal nerves (see below).

Remove the skin and the muscle dorsal to the anterior portion of the spinal column and cut away the dorsal part of the pectoral girdle. Do not cut too deeply or the spinal nerves will be destroyed.

Anterior Spinal Nerves. Each of these emerges by two roots through separate foramina in the fused vertebral column, the ventral root being anterior to the corresponding dorsal one. The anterior nerves converge to form the brachial plexus, made up mainly of three stout trunks, from which numerous branches spread through the pectoral fin. From the largest and most anterior of these trunks, approximately straight behind the medial

extremity of the last gill pouch, a rather large branch runs antero-ventrad to the floor of the pharynx. This is the hypobranchial nerve, which is mainly motor, though containing sensory elements also, and which foreshadows the hypoglossal nerve of higher forms.

Make an outline sketch of the brain and show the origin and distribution of the nerves described above.

Brain—ventral view.

After the study of the cranial nerves has been completed their roots may be severed a short distance from the brain, the spinal cord and the olfactory tracts may be transected and the brain may be lifted out of its case. This may best be accomplished by raising it carefully from in front and severing any connections which remain intact.

The three main regions already observed on the dorsal surface should be identified again.

I. Prosencephalon.

(*a*) The telencephalon appears as a solid transverse mass with the olfactory tracts connecting with it anterolaterally.

(*b*) The diencephalon is larger ventrally than dorsally.

1. Across its anterior end the optic nerves pass mediad to decussate in the median plane, forming the optic chiasma.
2. Behind the chiasma is a pair of large flattened swellings, the inferior lobes. These correspond approximately with the relatively smaller tuber cinereum of mammals, which is concerned with the regulation of visceral activities.
3. Attached just behind the inferior lobes is a large thin sac containing numerous blood vessels and hence frequently brown in colour on account of the coagulated blood within these. This sac, which spreads out to either side, is the saccus vasculosus, and corresponds with the mammalian infundibulum, the narrow tubular stalk which connects the hypophysis to the tuber cinereum.

   If care has not been taken to remove them with the brain, the saccus vasculosus and hypophysis may have remained in the floor of the cranium.
4. The hypophysis, or pituitary body, is a body about 4 mm. in diameter attached to the median part of the vascular sac and projecting behind it.

II. Mesencephalon.

The mesencephalon is small ventrally, and is concealed by the vascular sac and hypophysis. If they are raised or removed, the third nerve is seen emerging from the ventral surface of the mesencephalon just behind the inferior lobes. No definite boundary on the ventral surface delimits this region from the rhombencephalon.

III. Rhombencephalon.

This region presents few features of note from the ventral point of view. The most important point to be observed is the absence of a pons, which forms the ventral part of the metencephalon in mammals. The roots of cranial nerves V, VII, IX and X appear at the sides of the medulla oblongata.

IV. The arteries on the base of the brain may be noticed. The internal carotid approaches the brain at each side of the inferior lobes, where it gives off a branch to the optic nerve and one to the inferior lobes and then divides into an anterior cerebral artery to the cerebral hemisphere and a backwardly directed posterior cerebral artery which runs along the ventro-lateral aspect of the midbrain and hindbrain giving off numerous branches to these parts. Caudally the posterior cerebral arteries of the two sides unite on the anterior part of the spinal cord with a short median plexus, which is formed by the union of the vertebral arteries from behind. There is no anastomosis between the anterior cerebral arteries as in the mammals, to form a complete arterial circle on the base of the brain.

Draw the brain from a ventral viewpoint.

Brain—ventricles.

1. Fourth ventricle. If the brain be bisected by a clean cut in the median plane and the cerebellum be gently raised, the extent of this ventricle may be observed.
2. Cerebellar ventricle. The body of the elasmobranch cerebellum contains a large cavity which is continuous with the fourth ventricle.
3. Mesocoele. The midbrain does not contain only a narrow canal (cerebral aqueduct) as in the mammal, but has a relatively large ventricle which expands into the two optic lobes. It is continuous with the fourth ventricle behind and the third in front.

4. Third ventricle. A narrow cleft in the diencephalon expands somewhat laterad in the region of the inferior lobes and extends anteriorly into the lateral ventricles of the cerebral hemispheres.
5. Lateral ventricles. These are represented only by a short anterolateral extension from the third ventricle into the posterior part of each cerebral hemisphere, which region is almost solid in the skate—a secondary condition.
6. The cerebellum and the optic lobe should be neatly removed from one half of the bisected brain so as to expose the fourth ventricle and the mesocoele from above.

Draw the medial surface of the bisected brain.

SQUALUS ACANTHIAS LINNAEUS.

THE CRANIAL AND VISCERAL SKELETON OF THE DOGFISH

Chondrocranium

The chondrocranium of the dogfish is specialized in that certain additions have been made to the open trough which constituted the original brain case. A cartilaginous roof has developed to protect the brain from above and an anterior rostrum supports the snout region. The cartilage is continuous, with no sign of division into separate components.

Dorsal aspect

1. The rostrum. This presents a scoop-like hollow on its dorsal surface which opens backwards into the anterior end of the cranial cavity.
2. Anterior fontanelle. The opening into the anterior end of the cranial cavity.
3. Olfactory capsule. A massive projection at each side of the base of the rostrum.
4. Orbit. The large depression for the eye, etc., on each side behind the olfactory capsule.
5. Supraorbital crest. A shelf of cartilage extending from the olfactory capsule backwards above the orbit.

   Just behind the capsule appears a large foramen through which the superficial ophthalmic nerve emerges after passing from the orbit and a row of smaller foramina for branches of

the same nerve appears along the medial part of the supra-orbital crest.

The crest is continuous behind with a prominent projection (the postorbital process) on the auditory capsule.

6. Auditory (or otic) capsule. A large mass of cartilage behind the orbit.
7. Epiphyseal foramen. A minute median opening, just behind the anterior fontanelle, which allows the pineal body to emerge from the skull.
8. Parietal fossa. A median depression in the cranial roof between the auditory capsules. In this are two pairs of openings, both connecting with the interior of the auditory capsule. Through the smaller, anterior pair emerge the endo-lymphatic ducts, while the larger pair, the fenestrae, connect with the spaces round the membranous labyrinth and are closed by membranes in the intact animal.
9. Foramen magnum. The opening at the posterior end of the cranium through which the spinal cord connects with the brain.

Ventral aspect.

1. The rostrum bears a median keel at each side of which a rostral fenestra opens backwards into the cranial cavity.
2. Lateral to the rostral fenestra, the olfactory capsule presents a rather wide opening for the nostril, and within the capsule is the broad foramen for the olfactory bulb.
3. The preorbital process is a prominent ridge projecting laterad and ventrad from the back of the olfactory capsule and forming the anterior wall of the orbit.
4. Foramina for the optic, oculomotor, and trochlear nerves and for the trigemino-facial complex may be identified within the orbit.
5. Notochord. If there is available a specimen in which the broad basal plate forming the posterior part of the ventral surface is not concealed by the visceral arches, an opaque, whitish, median streak may be seen therein, indicating the presence there of the anterior part of the notochord. Just in front of it is the foramen for the internal carotid arteries.

SQUALUS ACANTHIAS LINNAEUS.

Visceral skeleton.

1. The pterygoquadrate bar (upper jaw) fits against the ventral surface of the chondrocranium medially and has a palatal process projecting dorsad into the middle of the orbit.
2. Meckel's cartilage (lower jaw) articulates postero-laterally with the pterygoquadrate bar.
3. Hyomandibular cartilage. Both the foregoing articulate at their caudal ends with this large cartilage, the medial end of which in turn articulates with the lateral surface of the auditory capsule.

   The two jaws together constitute the first visceral arch. Small, free, labial cartilages which lie near the angle of the mouth are lost in preparation of the specimens.
4. Hyoid arch. The hyomandibular cartilage belongs to the second visceral or hyoid arch, the rest of which is seen just behind Meckel's cartilage. It consists of a median basihyal and a pair of ceratohyal cartilages.
5. Five branchial arches (third to seventh visceral arches) lie behind the hyoid arch. Each is made up of several separate pieces of cartilage so that the shape of the whole may be changed by muscular action. These pieces are:—
   (*a*) pharyngobranchial (dorsal)
   (*b*) epibranchial (dorso-lateral)
   (*c*) ceratobranchial (ventro-lateral)
   (*d*) hypobranchial (ventral—in second, third, and fourth branchial arches only).
   (*e*) basibranchial. (A small median basibranchial connects the hypobranchials of the second arches on the two sides and a large one, the copula, articulates with the hypobranchials of arches three and four and with the ceratobranchials of the fifth arches. The copula has a posterior portion separated off from its main body.)

   It should be noted that the dorsal ends of the branchial arches do not articulate with any other skeletal structure.
6. The gill rays are slender rods, frequently removed in the preparation of the specimens, for the support of the branchial septa. They occur in rows attached to the hyomandibular, ceratohyal, epibranchial, and ceratobranchial cartilages.